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# Great Lakes Research Advisory Board, International Joint Commission: Semi-Annual Report: Research Needs: Great Lakes Water Quality

Great Lakes Research Advisory Board

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GREAT LAKES RESEARCH ADVISORY BOARD  
INTERNATIONAL JOINT COMMISSION  
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RESEARCH NEEDS: GREAT LAKES WATER QUALITY

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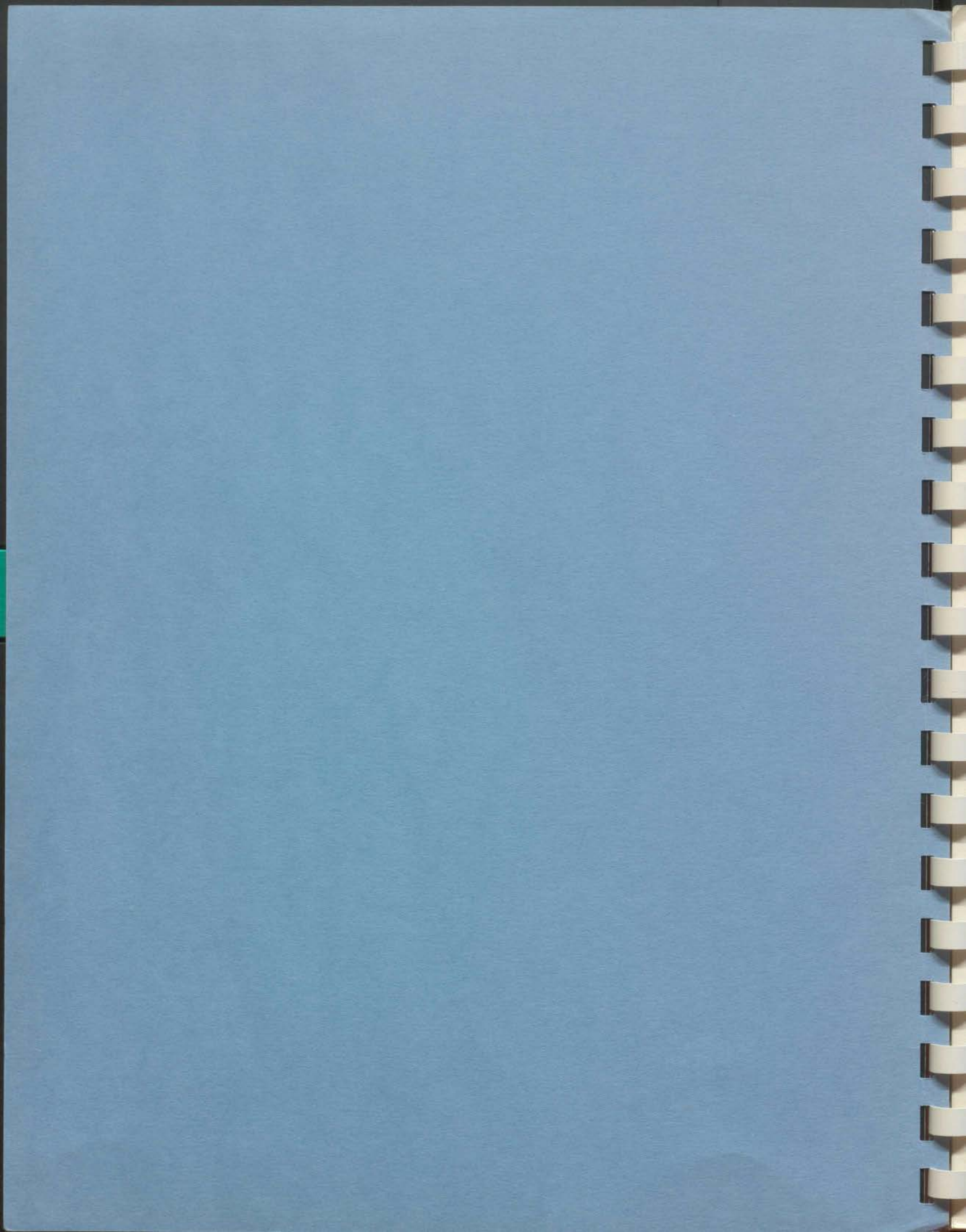
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## RESEARCH NEEDS: GREAT LAKES WATER QUALITY

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"Research Needs in Water Quality Criteria" (National Academy of Sciences, in press); Appendix 4, "Limnology" (Great Lakes Basin Commission draft); Proceedings of the Interagency Committee on Marine Science and Engineering Conference; and the contributions made at a seminar sponsored by the RAB at the 1973 conference of the International Association for Great Lakes Research. Based on these sources, a working group of the Research Advisory Board prepared a preliminary report for consideration.

The final selection by the Board of priority research needs were based in part on such criteria as inadequacy of current knowledge and ongoing research, effects on human health, irreversibility of consequences, societal effects, practicality of developing solutions, and timeliness of the problem. The items are not presented in order of priority. Other problems deemed of lesser urgency or priority and not appropriate for consideration at this time will be presented in subsequent contributions.

INTRODUCTION

In partial compliance with IJC Directive No. 1, the Great Lakes Research Advisory Board (RAB) submits this report on "Research Needs: Great Lakes Water Quality". Most importantly, the report identifies problems relative to water quality, where information is absent, inadequate, or not easily accessible; thus creating an atmosphere in which it is difficult to make rational, well-informed, scientifically-based management decisions for the Great Lakes.

The ten problems have a common thread: the relationship of water quality management and societal impact. Purists will claim that many of the identified needs are not truly research. The RAB concurs, but is unanimous in their feeling that our contribution, by identifying problem areas, will provide impetus for the research that will produce the information necessary for wise management decisions.

In addition to the RAB's internal resources, we drew from four sources: "Research Needs in Water Quality Criteria" (National Academy of Sciences, in press); Appendix 4, "Limnology" (Great Lakes Basin Commission draft); Proceedings of the Interagency Committee on Marine Science and Engineering Conference; and the contributions made at a seminar sponsored by the RAB at the 1973 conference of the International Association for Great Lakes Research. Based on these sources, a working group of the Research Advisory Board prepared a preliminary report for consideration.

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SCIENTIFIC BASIS FOR MONITORING

In the consensus opinion of the RAB the ten research needs presented in the past and present IJC studies of the water quality of the Great Lakes and their connecting channels have been directed primarily towards obtaining the physical, chemical and biological baseline data required for understanding various viewpoints in a unified voice to the public and our governments. To the extent that the sources of problems have been identified and the lake processes understood (both nearshore and lakewide) remedial measures have been recommended.

With the completion of baseline studies, and with a better understanding of lake processes, attention has turned towards the assessment of the continuing or modified changes in water quality of the Lakes - that is, towards monitoring. This is the case now for Lakes Erie and Ontario following completion of the Lower Lakes Study and implementation of some of its recommendations. Presumably this will also arise in Lakes Huron and Superior following completion of the present IJC Upper Lakes Reference study.

However, no satisfactory design for a Great Lakes monitoring program has yet evolved. The need for lakes assessment with regard to management actions, coupled with the substantial depth of data records which now exist, support the view that the time is ripe to design a monitor program so that it may be most effective and most economical. The potential substantial cost of such a program dictates the need for efficiency.

Monitoring implies two things: first, establishment of levels or rates of changes relative to particular water quality criteria; and secondly, it implies an ability to characterize a system with a set of key parameters. The first implication calls for identification of the objectives of the program and draws upon the expertise of both managers and scientists. The second problem calls forth the best efforts of the multidisciplinary scientific community in their understanding of lake processes.

### SCIENTIFIC BASIS FOR MONITORING

Past and present IJC studies of the water quality of the Great Lakes and their connecting channels have been directed primarily towards obtaining the physical, chemical and biological baseline data required for understanding water quality and identifying problem areas. To the extent that the sources of problems have been identified and the lake processes understood (both nearshore and lakewide) remedial measures have been recommended.

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Since the implementation of a monitor program probably will be multi-agency in nature, the management aspects of such a program is a prime element in the program design and a thorough investigation of the implications of this aspect of the program as it relates to data compatibility and availability requires study.

Given our best definition of the concerns for the Great Lakes system as a whole, individual lakes, parts of lakes or connecting channels, research effort is required on design studies to ensure an efficient and effective monitor program. Design studies will be required to define the concerns to a substantial degree of detail, to establish the key parameters relating to those concerns, to review past data on these parameters so as to be able to advise upon the techniques of sampling the methodologies required for sample analysis, the frequency and areal extent of sampling, and the possibilities for application of new technology in the monitoring program (e.g. automatic recording systems, remote sensing).

Above all, whatever monitor program is undertaken, a thorough test and evaluation of the program design is required.

Recommendation: Action should be taken to:

1. Set objectives by defining the IJC water quality concerns in the Great Lakes in detail - by problem and area;
2. Undertake design studies establishing water quality parameters or criteria related to those concerns defined in (1), whether they relate to specific areas, or the Great Lakes system as a whole;
3. Undertake design studies relating to sampling methods, sampling frequency and sample networks, analytical techniques, and the possibilities for the use of new technology, bearing in mind particularly the adequacy of past records of data.

Parallel to these should be considered the importance of setting



#### SCIENTIFIC BASIS FOR WATER QUALITY OBJECTIVES FOR HAZARDOUS MATERIALS

objectives, the need to conceive the management system required for the final program, the need for sufficient time to carry out the design studies, and the need to subject the program to test and evaluation.

Because water quality objectives have a direct impact on so many facets of water management and the ecosystems of the Great Lakes, their establishment, especially for hazardous materials, must have a sound scientific basis. To err in one direction imposes unnecessary regulatory and economic burdens; to err in another direction may lead to environmental degradation and accompanying social and economic upheaval.

An extensive body of knowledge exists on the acute toxicity of known toxic substances to various forms of aquatic life. Current water quality criteria are objectives based primarily on projection of these data to chronic exposure situations or to protect the ultimate consumer of contaminated organisms. The slowly-growing data bank on sub-lethal effects of chronic low-level exposure consistently reveals undesirable responses heretofore only suspected.

Recommendations: To provide the scientific basis necessary for meaningful water quality criteria and objectives additional research is recommended in the following areas:

1. Synergistic actions of toxicants, especially at sub-lethal levels.  
Studies embracing at least one complete life-cycle are the most reliable index of impairment although expensive and time-consuming to conduct as the combinations of contaminant, species and response are limitless.  
There is a need for the development of methods incorporating a variety of organisms.
2. Effects of physical-chemical conditions as modifiers.
3. Effect of time-concentration exposure framework on near-term and latent responses; e.g. intermittent exposure to chlorine in cooling water discharge.

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2. Effects of physical-chemical conditions as modifiers.
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- COLIFORMS AND WATER RECREATION
4. Confirmation of safe concentration projections derived from acute toxicity assays. Again this requires complete life-cycle exposures to sub-lethal levels. Development of rapid tests of sub-lethal effects which can be related to long-term tests of reproductive impairment or other behavioral or physiological responses is a critical need. This conclusion was also
  5. Determination of biologically-active chemical species, their relative biological availability and the factors affecting the activity and availability. Current criteria and objectives are most often based on the total amount of a chemical element present, but only a small percent of the chemical may be in a biologically-available form of significance to an organism, including the ultimate consumer, man.
  6. Significance and dynamics of the bioaccumulation process. While often considerable data are being accumulated on tissue storage of metals and organics in aquatic organisms, little knowledge exists on the significance of the residues either to the organisms themselves or to the consumer. with different media and enumeration techniques measuring different organisms which when identified biochemically, are found to be 40 - 95% true Enterobacteriaceae, not coliforms.
  7. By adhering to coliform standards we over-protect the health of the user and prohibit or withdraw the use of recreation areas because of nutrient-elevated coliform densities.
- As J.M.H. LaRiviere points out, the setting of a standard is an important economic act. We literally pay for our ignorance when we set a standard which is too high, such as a coliform standard which deprives citizens of the use of relatively safe waters.

## COLIFORMS AND WATER RECREATION

### Recommendations

The recent (1957-1973) literature seriously challenges the value of the coliform test as an indicator of health hazards to man in recreational waters. Much of this literature reveals that there is no proof that diseases are directly associated with large numbers of coliforms. This conclusion was also reached by the Public Health Activities Committee of the American Society of Civil Engineers in 1963.

The problems associated with using a coliform index as an indicator of health hazards are many; some of the important ones are listed below:

1. Coliforms have been shown to multiply in enriched waters while no such confirmation for pathogens is available;
2. Coliforms in effluents have been shown to survive chlorination, often multiplying to pre-chlorination levels, thus producing a false positive indication of potential health hazards;
3. The coliform enumeration procedures have been shown to be unreliable with different media and enumeration techniques measuring different organisms which, when identified biochemically, are found to be 40 - 95% true Enterobacteriaceae, not coliforms;
4. By adhering to coliform standards we over-protect the health of the user and prohibit or withdraw the use of recreation areas because of nutrient-elevated coliform densities.

As J.W.M. LaRiviere points out, the setting of a standard is an important economic act. We literally pay for our ignorance when we set a standard which is too high, such as a coliform standard which deprives citizens of the use of relatively safe waters.



#### ATMOSPHERIC INPUTS

##### Recommendation:

Additional specific research is required on the development of practical indices which protect water recreationists, not only from enteric infections, but also from upper respiratory tract and fungal infections. Increased incidence of illness suffered by swimmers as compared to non-swimmers is largely nasopharyngeal and epidermal in character. Coliforms can hardly be expected to provide an estimate of this type of risk. Direct epidemiological evidence is lacking to support any water pollution indices.

Bacteriological and epidemiological research should be directed towards evaluating the efficiency of using fecal coliforms (and more specifically which fecal coliforms), fecal streptococci and anaerobic lactobacilli as indicators to evaluate potential health hazards to recreationists. An equally important area requiring bacterial and epidemiological studies is the development of indices to protect users from upper respiratory tract and epidermal infections: specifically these studies should include Pseudomonas aeruginosa, coagulase positive staphylococci, Group A streptococci and water borne fungi.

the Lake Huron and Lake Superior basins. All of the stations in the three networks collect bulk precipitation samples (rainfall, snowfall and dry fallout) and analyze for nutrients and trace metals.

Data from CCIM's Lake Ontario basin stations for 1970-71 indicate that from 5 to 14% of the total phosphorus and 12 to 14% of the total nitrogen inputs to the lake comes from precipitation. Higher percentages were indicated for some of the trace metals. In the Lake Superior and Huron basins preliminary indications from both CCIM and McMaster data suggest that precipitation may be a major source of nutrients to these lakes.

ATMOSPHERIC INPUTS

The role of atmospheric inputs (rainfall, snowfall and dustfall) in the chemical cycles of the Great Lakes has been relatively ignored until recently. Research in other areas of the world, notably Sweden, has shown that precipitation contains considerable quantities of a variety of substances, including nutrients and toxicants. Thus the ability to define the contribution by precipitation to the nutrient budgets and chemical contamination of the Great Lakes is of importance.

The present level of investigation consists of three studies in the Great Lakes Basin. In 1969 the Canada Centre for Inland Waters commenced operating a network which now contains 18 land and island based precipitation sampling sites in the International Great Lakes Basin. In 1970 McMaster University, sponsored by the Ontario Ministry of the Environment, established a network of some 26 stations in the Sudbury region of the Lake Huron basin. The upper lakes states and the Environmental Protection Agency currently are establishing a network of 10 - 12 stations in the U.S. portion of the Lake Huron and Lake Superior basins. All of the stations in the three networks collect bulk precipitation samples (rainfall, snowfall and dry fallout) and analyze for nutrients and trace metals.

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Recommendation:

Research needs in precipitation chemistry and atmospheric inputs to the Great Lakes include:

1. Better definition of loading estimates and the biological significance of atmospheric inputs by expansion of the land-based sampling network, obtaining precipitation samples over the open lake on a regular basis, and immediate analysis of the precipitation to determine free metal concentrations and soluble nutrient concentrations in biologically available form;
2. Separation of the atmospheric loading to define what portion of the total load is input by rainfall and what portion by dustfall;
3. Definition and identification of sources of the substances in atmospheric fallout by determining the relationship between air mass movement and precipitation chemistry and by the use of natural tracers;
4. Increased scope of analysis to include atmospheric inputs of toxic organics; i.e. pesticides, PCB's.

Regional and transboundary experiments involving "talking drift bottles" for continuous telemetry can demonstrate horizontal dispersal over local and regional scales for periods of up to several weeks.

There is a need to know and understand the transport processes that become important after pollutants pass from the nearshore water into the open

### LAKE DYNAMICS

Within the framework of the IJC mission, the most pressing gaps in our knowledge and predictive capability in lake physics are related to transport and dispersal of introduced materials and heat. While the mechanisms of transport and dispersal are understood and typical rates are known in a general fashion, and while some detailed studies have been or are being made at particular sites in the Great Lakes and oceans, for useful predictability we need better models, verified by properly designed and executed field measurements, of dispersal on local scales (1 to 5 miles) and regional or whole-basin scales (5 to 100 miles). This entails an adequate understanding of the currents and their driving mechanisms (particularly nearshore) and the spatial and seasonal variability of these currents and the associated intensity of turbulence.

Recommendation: Local scale experiments are needed on plumes that are sufficiently large, adequately instrumented, and capable of manipulation (for example continuous or intermittent labeling, turning on and off at will) for (1) determination of local entrainment and turbulence, and (2) establishment of statistical variability of lake effects. The latter effort should be combined with a baseline "underwater weather" station, operating continuously with reliable instruments. This major effort must be expended to clearly understand and develop predictive capabilities for the behavior of nearshore currents and of larger scale long-shore currents.

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There is a need to know and understand the transport processes that become important after pollutants pass from the nearshore water into the open



lake -- better estimates of "flushing times" for example, on which predictions of whole-basin effects will depend.

International, interagency and interdisciplinary consultation, planning and cooperation should enter into model development and, above all, model verification by field observations. Model development should consider the limitations and potentialities of modelling, not only physical mechanisms, but those chemical and biological processes which determine "water quality" within the IJC context. Some useful predictability in this field is a sorely needed product, and much effort and money are probably now being wasted without it. We believe that we shall find the limitations to be, not the mathematical tools, but a sufficient understanding of the biological and biochemical mechanisms.

Recommendation: Research into the development of predictive models of Great Lakes dynamics should be encouraged. This should involve cooperation between countries, agencies and disciplines and include field studies to verify the models. Such research and development should provide more reliable information to support the IJC water quality objectives. Increased predictive capability will enhance our ability to make wise management decisions.

#### NUTRIENT INPUTS AS RELATED TO TROPHIC STAGE OF LAKES

A good deal of research is presently being conducted on nutrient inputs to the Great Lakes in the hope of understanding the relationship between these inputs and the stage of eutrophication. Though a considerable amount of data for this purpose is available, there is still uncertainty in regard to the degree - in terms of quantification of this relationship - to which input and reaction of the system is coupled. Statistical aspects connected with the data collection are poorly defined to date.

#### Recommendations:

Strengthening of research in the following areas is needed:

1. Improvement of our understanding of the phenomenological relationship between nutrient input and fertility of lakes in terms of algal standing crop (chlorophyll) and dominant algal groups, and their effects on transparency, epilimnetic nutrients and hypolimnetic oxygen depletion. Lower priority should be attached to the reaction of individual species but this aspect should not be ignored.
2. Improvement of our understanding of nutrient input and its effects on inshore areas as related to physical dynamics including currents, diffusion, upwelling, waves and geomorphological properties and dynamics. Increased attention should be directed to the Cladophora problem.
3. Improvement of our ability to predict nutrient fluxes and their seasonal variations from land-based sources, with special emphasis on non-point sources.

Nutrient in the above context refers primarily to the elements phosphorus and nitrogen, which require immediate attention. Lower priority should be given, at this time, to trace elements (considering their effects as algal growth stimulators as well as toxicants) and organic, growth and controlling factors. Over the long term serious consideration should be given to these



WASTE / HEAT AND COOLING WATER USE

factors.

4. Consideration of methodological aspects. There is an immediate need to improve the analytical techniques for pigment (chlorophyll) determinations in terms of reliability of technique and routine procedures.
5. Improvement of sampling design. Immediate attention should be given to the design of more rational sampling programs so as to optimize temporal and spatial resolution, statistical significance and to minimize cost of operation.

An associated concern involves the fate of organisms entrained at the intakes, passed through the condensers, and discharged with the cooling water. The great volumes of water passing through the plants could result in sufficient zooplankton and planktonic fish larvae and fry to have a significant effect on their populations.

The Canada-U.S. Agreement on Great Lakes Water Quality requires the establishment of refined objectives for temperatures and thus some regulation of waste heat discharges to the Great Lakes. Such regulations might take the form of limits on lake-water temperature increases, limits on temperature increases permitted in effluents, controls on total heat energy permitted to be discharged to a body of water or portion thereof, and/or regulations and requirements on siting and design of condensers and discharge structures. Presently available data and understanding are inadequate to definitively assess the degree of protection required or the likely environmental and economic consequences of alternatives to direct discharge of waste heat to waters. Thus there is an urgent need for a better scientific basis on which to establish objectives and regulations.

## WASTE HEAT AND COOLING WATER USE

The existing and projected increase in nuclear and conventional thermal-electric power generation in the Great Lakes basin may result in significant temperature changes and ecological effects due to waste heat discharges. It has been estimated that the total thermal load to the Great Lakes by the end of the century will have increased 10 to 11 times over existing waste heat release. Models to predict heat distribution are being developed. There is a great need for a better understanding of the impact of altered temperatures on ecosystems, especially in near-shore zones.

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POTENTIAL RADIATION HAZARDS

Recommendation:

Completed and ongoing research, including that of the power industry, should be catalogued and assessed. Many individual on-site studies have been made, but there is a great need for generalizations which could suggest reasonable "base line" objectives for preserving water quality. Comparative biological studies of the effects of heat and long term temperature rises should be emphasized. Energy dissipation rates in various types of coastal zones must be assessed and models improved for prediction of temperature patterns arising from heated plumes. Existing near-shore temperature regimes must be more accurately known along with their associated aquatic ecosystems. Efficiency of the total investigative program could be vastly increased through coordination of efforts. grave considerations must be taken when the potential persistence of contamination is factored in. Assessment of environmental consequences, in addition to human and property damage, must be made, and the public and their agencies in evaluating this environmental issue.

The amount of radioactivity found in the environment as a result of present day reactor operations and discharges is far less than that due to natural background and far less than nuclear weapons testing. The question has been raised whether this will continue to be the case as more nuclear plants come into existence. How much radioactivity can safely be released to the environment from operations associated with power production is a highly contentious question. The necessity of balancing risk and benefits is obvious, but subject to great uncertainty.

Recommendation:

Research to develop scenarios of environmental consequences of major nuclear reactor accidents involving large scale releases of radioactive materials in Great Lakes waters is of high priority. Information of this nature may

POTENTIAL RADIATION HAZARDS

In the Great Lakes Basin an approximate ten-fold increase in electric power generation, mostly nuclear, is projected by the year 2,000 A.D. While the probability of an event occurring which would disperse a nuclear reactor core is remote, such an event is a possibility. The Atomic Energy Control Board of Canada and the U. S. Atomic Energy Commission have reported on the hypothetical consequences of theoretical accidents mostly in terms of property damage, personal injury and loss of life. These estimates are very great, but the RAB expresses concern for accompanying damage to Great Lakes water quality and their ecosystems. Such questions as contamination of public water supplies drawn from the lakes and the hazards associated with contaminated fish are grave considerations, especially when the potential persistence of contamination is factored in. Scenarios of environmental consequences, in addition to human and property damage, would aid scientists, the public and their agencies in evaluating this controversial issue.

The amounts of radioactivity found in the environment as a result of present day reactor operations are indistinguishable from those due to natural background and fallout from nuclear-weapons testing. The question has been raised whether this will continue to be the case as more nuclear plants come into existence. How much radioactivity can safely be released to the environment from operations connected with power production is a highly contentious question. The necessity of balancing risk and benefits is obvious, but subject to great uncertainty.

Recommendation:

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influence licensing authorities in site selection and safety standards to the benefit of the public.

Of lesser importance, but still of concern to the RAB, is a review of environmental monitoring programs and the significance of normal operational releases of radioactivity to Great Lakes water quality and biological assemblages.

practices including society's preference for planning. Trends reflect current increased regulatory activities. To improve future water quality management decisions of the future a data base of relationships between activities to current water quality must be coupled with the best available projections of our culture's future patterns, attitudes and actions.

Development in the lakes' watersheds varies from the highly developed watersheds of the lower lakes containing major urban and industrial areas and intensively farmed land to the relatively undeveloped lands around Lake Superior. There is a tendency among forecasters to be optimistic about the partially-virginal upper lakes and to show less enthusiasm for the more worn lower lakes. Projection of future development in the watersheds of all the lakes is necessary. Water quality improvement in the lower lakes should be of equal or greater significance than protection of the upper lakes.

Future effects on water quality cannot be predicted without the ability to forecast types of development, anticipated actions and concentrations of population densities, technological dynamics, and an appreciation of governmental and public willingness to curb pollution. Initial attempts have been made to forecast such development, attitudes and technological changes, but there is a need for greater effort in developing accurate mathematical models which will incorporate the implications of a chosen scenario on water quality so that water managers can forecast the water quality which would result from a particular course of action. Appropriate and realistic scenarios for the future can only be developed as we learn more about long-range plans of other

FORECASTING DEVELOPMENT

Cultural activities in their watersheds affect the quality of Great Lake's waters. Changes in water quality and accompanying biological phenomena over the past century reflect land use; industrial development; population densities; social priorities, needs, ethics and innovations; and agricultural practices including society's preference for blemish-free produce. Recent trends reflect current increased regulatory activities. To prepare for the water quality management decisions of the future a data base relating cultural activities to current water quality must be coupled with the best possible projections of our culture's future patterns, attitudes and abilities.

Development in the lakes' watersheds varies from the highly developed watersheds of the lower lakes containing major urban and industrial areas and intensively farmed land to the relatively undeveloped lands around Lake Huron and Superior. There is a tendency among forecasters to be enamoured with the partially-virginal upper lakes and to show less enthusiasm for the more shop-worn lower lakes. Projection of future development in the watersheds of all the lakes is necessary. Water quality improvement in the lower lakes could be of equal or greater significance than protection of the upper lakes.

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agencies and governments, public objectives, and the national conscience with regard to environmental protection.

Recommendation: Existing forecasts, long-range plans, governmental proposals and public objectives should be systematically collected, inventoried and analyzed for the purpose of predicting effects upon water quality. New ways should be developed to incorporate the wishes of the public at the level where a given scenario directly affects their social and economic desires and well-being both from the standpoint of land use as well as the associated water resource.

## OPERATIONAL EFFICIENCY OF MUNICIPAL WASTEWATER TREATMENT PLANTS

A multi-million dollar investment of federal, provincial and state financial resources exists in the form of municipal wastewater treatment facilities in the Great Lakes basin. Informal discussions with professionals familiar with these facilities reveal that these facilities do not always achieve their design performance in the removal of pollutants from the wastewaters influent to them. The potential exists, with minimum capital expense, to reduce the pollution load to the Great Lakes by improving the efficiency of existing facilities. While a more diligent application of existing technical and management knowhow would undoubtedly improve efficiencies, there is a considerable lack of information as to the magnitude of the problem and the true value of current management and technical practices.

Reasons commonly advanced for poor performance of facilities include inadequate design, insufficient operator training, low level of operator competence, low operator salary, insufficient operating budgets, insufficient monitoring of discharge, and lack of incentive to achieve peak efficiency. However, there have been no studies that quantify the extent of the problem or attempt to determine which of the above factors, if any, are significant. The value of specific management, technical alternatives, or both, in improvement of plant efficiencies is unknown. Such factors as mode of technology employed, level of operator training, degree of automation, and administrative and jurisdictional problems should be correlated with performance of the treatment plants.

### Recommendation:

A study should be undertaken to collect and interpret data on factors that can affect municipal wastewater treatment plant operation efficiencies. The objectives should be to identify and quantify the effects of specific technical and management practices on treatment plant operation efficiencies and to determine



the extent to which improved operational efficiencies can reduce the loading of pollutants to the Great Lakes. Much of the foregoing would also apply to operation of industrial wastewater treatment plants.

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